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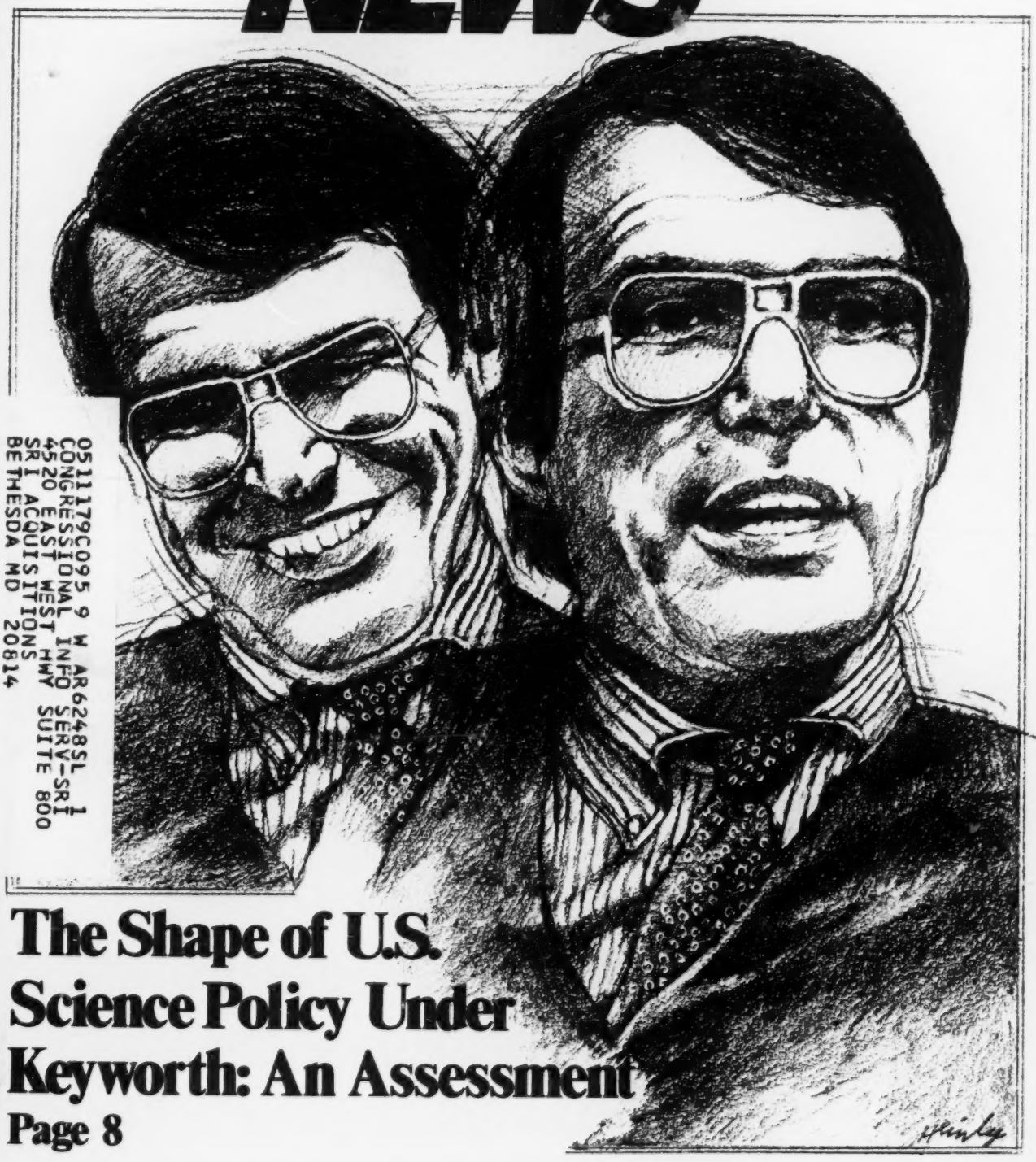
CHEMICAL & ENGINEERING

NEWS



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The Shape of U.S. Science Policy Under Keyworth: An Assessment

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NEWS

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Presidential Science Adviser George Keyworth has scored well with the scientific community, especially by increasing federal support for basic research. **Page 8**

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Peers Rate Keyworth Generally High as President's Science Adviser

Keyworth gets high marks on White House access and support for basic science, low marks on intellectual independence; doubts rise over shape of science advice in new Administration

Wil Lepkowski, C&EN Washington

Three and a half years ago, President Reagan surprised the scientific community and appointed as his science adviser a physicist unknown in Washington. His name was George A. (Jay) Keyworth II, son of a New England furniture factory president, a nuclear physicist at Los Alamos National Laboratory, and a protégé of Edward Teller. Teller is, as most know, the physicist who is as famous for his conservative, anti-Soviet politics as for his leading role in the development of the hydrogen bomb.

C&EN staff photo

Keyworth: forced new thinking

If Keyworth, 44, was a nobody then, he isn't now. As science adviser he has triggered more controversy and debate over technical priorities than any equally prominent science policy figure in the past. But the reason for this is less his provocative personality than history's ebbs and flows. Conservative by nature, Keyworth came in to serve a conservative Administration, with its blend of aggressive anticommunism and absolutist belief in the moral imperative of the business ethic. So he had a power base and he acted on it, adding an effervescent zeal for scientific discovery.

Keyworth is being given credit for the biggest series of increases for basic research since the middle 1960s, when funding for science was in its heyday. During Reagan's tenure, basic science funding has risen from around $4.8 billion in fiscal 1981 to $6.2 billion in the current fiscal year. The scientific community is happy with Keyworth. He has argued successfully for what they want, despite continuing strong differences over arms control issues.

He established a White House Science Council of top scientists and engineers in the country. This group reports not to the President, but to him, unlike the old President's Science Advisory Committee (PSAC) for which the old science establishment still hankers. He told establishment titans early on that they had to begin setting priorities in scientific research, and they did. He helped produce the current climate of close—today almost frenzied—research cooperation between universities and industry. He forced new thinking in the field and gave some excitement to the connections between science and national goals.

Under Keyworth, the National Science Foundation has drastically upgraded engineering research and education through an ambitious goal of funding several engineering research centers at universities around the country. Thanks to efforts of his office, agricultural research is becoming modernized and organizationally revamped toward capitalizing on developments in molecular biology.

Keyworth also pushed successfully for larger funding for competitive research in the Agriculture Department. He reoriented the Department of Energy's national laboratories toward more cooperation with industry and universities. A special OSTP panel issued a report favoring quick regulatory action to prevent further acid rain pollution. And Keyworth has tried to see to it that the Administration develops a coherent policy

on cancer prevention in the environment and workplace.

In short, Keyworth seems to have sought not only to master science policy but to take charge of it. So much so that sources say he harbors visions of becoming the country's first Secretary of Science & Technology.

It is possible, of course, to overplay the influence of a science adviser in any Administration. Science advisers whoever they are may impress and even intimidate their technical peers, but to operatives within the White House inner circle, they are seen more as potential anchors on the political ship. The reason is that the scientist's mental framework dictates honesty rather than expedience.

But Keyworth, hawkish, boyishly enthusiastic about science and technology, and bullish on the free enterprise system, could operate honestly within that ideological mindset of the Reagan White House. It was Teller, after all, who urged that Keyworth be appointed after several more senior and savvy science and technology figures refused to be considered. And since Keyworth has on many occasions conferred on Teller an almost spiritual role in his (Keyworth's) development, the appointment made more than good sense.

So what the nation has today is science and technology fashioned in the context of a conservative ideology. It is, in a sense, the Office of Management & Budget's job to fashion and carry out budget decisions congenial to the current ideology. And it is Keyworth's job to explain them. As Presidential envoy to the scientific community, Keyworth has been tireless. He also has been an indefatigable spokesman for excellence in scientific research.

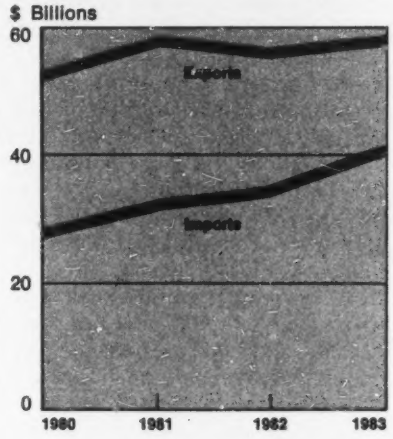
Unfortunately, all this makes him a little suspect with the establishment. For although he has helped give it what it wants in terms of funds and programs, it does not feel he has quite succeeded in balancing party loyalty with complete scientific integrity. Many establishment figures, in fact, are working quietly to help Keyworth grow in his job despite their disagreement with Administration policies.

So people do understand. "I think that considering the general circumstances a science adviser is in," says long-time Washington science watcher Philip Abelson, soon to retire as editor of *Science*, "Keyworth has done a better than average job. There is a jungle in the inner reaches in the White House. Your heart may be the purest and your wisdom the greatest, but if you don't have any instinct in knowing how to thread your way through that jungle you're no damn good."

So judgments aside for the moment, Keyworth has succeeded in articulating a "science policy" for the country. It is that federal science exists to serve industrial competitiveness. Ten years ago, the sentiment was exactly the opposite. Science came under criticism for ignoring quality of life issues and serving the military cause in Vietnam. Those attitudes hold no more. It is a different period of history. And the change has been stunningly swift. For the first time in memory, for example, Massachusetts Institute of Technology reports that research funding from private sources now exceeds grants coming from NSF.

Upbeat is one word that surely characterizes Keyworth. Hear him on policy for science and mathematics education spoken before a group of science writers last month:

High-technology imports growing faster than exports



Note: High technology is defined by such products as communications equipment, electronic components, scientific instruments, industrial chemicals, resins, fibers, and drugs and medicines. **Source:** Department of Commerce

Government funding of research and development would surpass $50 billion in 1985

Federal funds for R&D by budget function

$ Millions	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
National defense	$10,430	$11,864	$12,899	$13,791	$14,946	$18,413	$22,070	$24,936	$29,275	$36,975
Health	2,351	2,629	2,968	3,401	3,694	3,871	3,869	4,298	4,601	4,913
Space research & technology	3,130	2,924	2,962	3,009	2,981	2,896	2,584	2,134	2,286	2,683
Energy	1,849	2,582	3,134	3,461	3,603	3,501	3,012	2,578	2,585	2,422
General science	858	974	1,050	1,119	1,223	1,340	1,359	1,502	1,717	1,942
Transportation	631	708	768	798	888	870	791	876	1,091	1,148
Natural resources & environment	683	753	904	1,010	999	1,061	965	952	985	900
Agriculture	383	457	501	552	583	659	693	745	760	795
TOTAL	$20,780	$23,542	$25,994	$28,060	$30,017	$33,319	$35,968	$38,768	$44,367	$52,880

Source: National Science Foundation

"Incredibly good things are happening today. It's incredibly anachronistic for national leaders to be talking about the federal government leading a charge for science and math education when we are seeing a better job occurring in states and regions than anything the federal government has ever been able to accomplish. The North Carolina School of Science & Mathematics is a model no federal government could ever devise. If the federal government supported that it would be crass elitism. More and more bond issues are being passed to support standards and teacher salaries. Teachers clearly are drastically underpaid. They have to be elevated [in stature] to reflect their value.

"The government is trying to respond to this mood by high-leverage activities. We brought the best teachers to Washington. They got awards, saw the President. It was enormous leverage, though it cost next to nothing. Some of us are very excited about the fact that new technologies offer the possibility to pay careful attention to the learning process. We can ask ourselves how we can use this technology to make use of the student's learning process far more efficiently. I think the field of cognitive science is truly beginning to display vestiges of true science. And that field along with technology will help us develop a science of learning as contrasted with the science of teaching."

Keyworth is refreshingly candid about his assessments of what he feels needs changing in government science and technology. Take, for example, these comments he made to the same meeting on two agencies currently undergoing scrutiny:

"We haven't as yet been able to wrestle effectively with the National Oceanographic & Atmospheric Administration. There's a lot of poor quality work there. I worry about the National Institutes of Health as much as anything. There they are making the transition between an era when biology was supported for its impact on biomedical research and health care, to a time when biology represents broad new disciplines that impact upon everything from mining of materials to industrial chemicals.

"We are not making that transition well. We have not for 10 years paid adequate attention in our biomedical research priorities and allocations to the kind of people we're drawing into these fields. ... The willingness and ability of NIH to address the kind of talent that comes out of its research program has not been up to the needs."

In short, Keyworth is identified with designing a science and technology policy more geared to the capitalist market system than any science adviser in the 40-year history of the ilk. And he apparently isn't satisfied to stop there. For if Keyworth's prayers are answered, President Reagan will announce next year plans for establishing a Department of Science & Technology. The President's Commission on Industrial Competitiveness, comprised of several executives from high-technology companies, made the recommendation for such a department at its meeting in Dallas in late October (C&EN, Nov. 19, page 6).

But the White House staff may have other plans. The President may announce, instead, a drastic cutback in the executive branch. Sources who can't be named are beginning to say that the White House inner circle is contemplating elimination of Keyworth's position and OSTP. Some have been suggesting that Keyworth is hoping the commission possesses enough influence with the President to endorse his function and, in fact, elevate it. In any case, the science adviser has become less shy about promoting the idea. And, in the end, if the White House decides the President needs merely a special assistant to the President for science and technology, Keyworth could be well positioned.

Meanwhile, Keyworth leads the cheers for federal support for good science, often to a fault. "Keyworth is faster to the tin cup than any science adviser before him," says one long-time participant in the wars over science and technology budgets. "The worst example of that was OSTP's attempt to establish the Berkeley materials lab without much input from the materials science community." This source was referring to Keyworth's attempts to establish at the Lawrence Berkeley Laboratory an Advanced Materials Research Center. Materials scientists around the country protested that they were not consulted and the lab, though now established, lacks the expensive synchrotron light source that was to be its centerpiece.

Even Republican colleagues fault him on that one. Edward E. David Jr., a member of Keyworth's science council, science adviser under President Nixon, and currently president of Exxon Research & Engineering Co., says, "I think one of the mistakes Jay made was his support of the Berkeley center. That's one of the few things that led to all the pork barreling of university research facilities we're seeing today."

One technology policy figure who clearly has high grades for Keyworth is Robert M. White, president of the National Academy of Engineering and for many years director of the National Oceanographic & Atmospheric Administration. The engineering academy performed the study on engineering education that led to establishment of NSF's engineering research centers program. The first engineering research centers grants are due to be announced in March.

"I think Jay Keyworth has been enormously successful as science adviser on whatever measures one might use," says White. "Funding for basic science has grown faster than at any time during the past 13 years. He has fashioned a conscious policy to make sure of that funding support in areas on which the future of the country depends. I think also that he has recognized the need for major changes in engineering education, training, and support. Out of that has come NSF's engineering research centers program. You have to give the guy credit. He has reached out to the community [to determine priorities for science and technology] and has been very upbeat."

Another big booster is Roland W. Schmitt, senior vice president for corporate technology at General Electric and chairman of the National Science Board. Says Schmitt: "I think Jay has been an extraordinarily

Keyworth's views on selected subjects

On the National Science Foundation's Engineering Research Centers:
"The centers are means by which multiple disciplines can get together outside of the departmental context of presumed problems. But most of all, the program is a cultural bridge. And it's a mechanism that we'll see expanding beyond engineering and very much encompassing the sciences, too. Suppose industry wants to draw upon academic talent to address defects in semiconductor gallium arsenide. Where do they go? To a physics department to get the materials science experts? To a chemistry department? To an engineering department? The problem is that universities are not structured to solve problems. They're structured along disciplines so they ensure that someone who gets a degree in any area of science has met certain standards. We also need problem-solving mechanisms on campus so that students will become familiar with the types of problems they'll be solving when they get outside. That way we can narrow the cultural gap between the ivory tower and competitive industry."

On establishing a Cabinet-level Department of Science & Technology:
"It's time we gave very hard thought to how we handle one of the most precious resources we have, our science and technology base. Maintaining the cutting edge in science and technology is absolutely essential to our future. It has got to be an elevated priority. It deserves to be closer to the policy-forming apparatus that the President maintains, and we need a more direct mandate to couple policy and implementation. There's considerable interest in it among White House staff. Many find it an interesting issue worthy of some deliberation."

On charges that Rep. Don Fuqua (D.-Fla.) sidestepped the peer review process in securing for Florida State University a supercomputer funded by the Department of Energy:
"I think Don Fuqua's been erroneously maligned. There has been blatant pork. And that came in through universities that went to lobbying organizations in Washington and tried to literally play the process. That is sheer unadulterated pork. Don talked to me from the very beginning about that supercomputer opportunity in Florida. He was interested in it; it was spontaneous in Florida, and from the very beginning his argument to me was, 'Jay, I want nothing but quality in my state and I'd appreciate your technical judgment as to the quality of that project.' He was using me for my honest opinion of whether this was a first-class facility. First of all, I said I would give him my opinion. Second, I gave him my opinion. I said they have a very good and very promising computer science capability. What they have in mind is very much what we are trying to do in stimulating supercomputers, and I will continue to give my objective views on it. I did all the way along. There was no pork. It bore no resemblance to what was being done via the lobbying process. There was careful comparison to other opportunities in other agencies."

On whether the time is ripe for another space spectacular:
"I think the American public needs to better understand what the opportunities are in manned space flight, whether they be Mars, asteroids, the manned lunar station, whatever. And I think the public needs to decide whether it is an important priority to them. I don't think we should look back to the Apollo project, but I think we should recognize that the public owns the civil space program. It is more public property than almost any federal program that I'm intimate with. And I think the public should make that decision. I look forward to the commission on space that we're working with now."

On the Star Wars controversy:
"Star Wars has been very much caught up in the political campaign. It became a highly political issue at the outset. You will find a remarkable alignment between political inclination and opposition or endorsement of Star Wars and I think it's much too serious an issue for that. One of the things I found most disturbing was the fact that there are hundreds of thousands of scientists in the U.S. but only about 20 people who have criticized every strategic step taken by this and the previous Administration. There have been constant accusations that if the President's Science Advisory Committee had been around it would have reviewed it. Well, we have a group called the White House Science Council. It was intimately involved. The only difference is that the White House Science Council has achieved its credibility by being quiet. I admit that we as an Administration certainly could have done a better job of working together amongst us all to develop a clear-cut strategy and policy associated with it."

effective science adviser. I remember when he went into the office and made it clear that he would act as a member of the President's staff and on behalf of the President, rather than as a representative of the technical community in the White House. That didn't go over well with the community. Yet everyone would have to agree now that he was extremely effective."

Further praise comes from Ivan L. Bennett Jr., dean of New York University school of medicine and a deputy director of the White House Office of Science & Technology in the late 1960s. "I think that Keyworth has done a very good job," says Bennett. "He was a relative unknown when he was appointed and has grown into the job, and has become very effective. He's been effective in the sense that he has to the best of his ability given the President advice on matters of national policy in science and technology. He has demonstrated that there is someone in the White House who is listening to him. His advice has come from judicious tasking of policy issues, like the Academy of Sciences' priority reports. He has built on the foundations of Frank Press. He has been very skillful at treading the fine line between being the representative of the scientific community and being the President's science adviser."

Keyworth is very much the team player more than

C&EN staff photo

White (left), Golden (center), and Schmitt praise Keyworth, feel that he has been a very effective science adviser

he is the generator of new ideas and informed criticism within the White House staff. So in that sense, though bright, he could be in danger of being intellectually the most compromising science adviser by virtue of the Administration he serves.

He had no apparent role in the debate over yellow rain, had little public to say about scientific secrecy in the face of national security needs (indeed, sources say, he has little role at all in the inner circle of national security matters, where outside technological advice is most needed), and cannot be regarded as the type of thinker who ponders science in the context of the broader needs of humanity and nature.

Consider this quote from a speech by Keyworth to the Woodrow Wilson Center in Washington two months ago: "Only a few years ago," Keyworth said, the U.S. was in "near panic" over the technological threat from Japan and Western Europe, who were "10 feet tall and growing." But "our perceptions have changed," he said. "We've recuperated from our brief lapse of common sense. Our recovery over the past few years—and by that I mean both economic and emotional recovery—has transformed our attitudes toward these foreign challenges. When we look around the country today, we see very few industries still trying to hide from competition, and most of them are ready to take on all comers."

But on specifics, Keyworth wasn't so keen as his rhetoric. Which industries were trying to hide from competition? Steel? And isn't it still? Auto? Isn't it doing better than ever, yet still insisting on Japanese import quotas? Machine tools? Is it really any better off in its balance of trade figures?

Keyworth, who is on record as minimizing the importance of the social sciences, says the country has recovered "emotionally." But on what scale of measurement? Who has recovered? And of those who were emotionally destitute, were they the urban and rural blacks? Farmers? Indeed, bankers? And if so, are they feeling any better?

"What bothers me most about Keyworth," says a Congressional staff person who has dealt with science policy issues over the years, "is his poor communication with Congress and the public. The White House science group is a closed society. It doesn't care to communicate with the rest of the world. In his hopes that the President will establish a Department of Science, you would have thought he would have come up to the Hill and talked to all the key committee chairmen to pave the way for the politics that will be involved."

Any talking to Congress about a science department at this time probably would be premature. And all Keyworth is saying, anyway, is that the topic deserves serious discussion. Moreover, he does have that handicap as a scientist: A science adviser cannot be expected to serve above the politics of the Administration in power. Lee Dubridge, observes John M. Logsdon, director of the program on science and technology policy at George Washington University, was the last science adviser who came in defining his role as the representative of establishment science to the White House. But in short order he was disabused of the attitude by the Nixon White House. So after little more than a year, he resigned.

"I think the problem with Keyworth," comments Harvey Brooks, professor of technology and public policy at Harvard University, "is that his advice has had too little independence from the ideology of the Administration. Frank Press straddled the line successfully between fulfilling the staff function to the President and reflecting the kind of independent advisory role a science adviser would symbolize. Keyworth is too subservient to Presidential politics. The best example is the Strategic Defense Initiative (Star Wars). This is an area where the science advisory office could

have been acting as a confidential and responsible critic. But as far as I can make out, Keyworth was a proponent of it without understanding all the issues very well.

"In the old days, a PSAC would have jumped in and kept the President from going out on a limb. In another area, Keyworth, by promoting the Berkeley advanced materials lab, seemed to invite Congressional initiatives into establishing other centers."

Today's science office, adds Brooks, "does not reflect the social changes running through society." But he says a science adviser would run into a political "dead end" by promoting understanding in today's White House. "The whole atmosphere," says Brooks, "is that of an Administration out of tune. Keyworth came in without any broad understanding of the broader issues."

John P. Holdren, a physicist at the University of California, Berkeley, and a member of the largely invisible Scientists & Engineers for Mondale during the election campaign, gives credit to Keyworth for his "forthrightness" in explaining his role as the President's science adviser. "I admire him for his willingness to tackle top issues head on as he has repeatedly done," says Holdren. "I admire him for the vigor with which he has argued the case for basic research within the Reagan Administration. I imagine that in many respects he's had an uphill fight. He has fought for science capably and in many respects successfully."

But there the compliments cease. "Unfortunate trends," such as the increase in the defense budget, decrease in the size of nondefense research and development, and curtailment of scientific exchanges with East bloc countries are bad enough, says Holdren. But the Administration also shows "profound misunderstanding of the nature of the energy problem and ways in which market incentives fail to address important aspects of the problem or actually make them worse.

"More remarkable," says Holdren, "is that Reagan has not even applied consistently this market-oriented view. The Administration has repeatedly requested more for fission R&D than Congress has been willing to appropriate. And the sum for nuclear fission R&D still exceeds the sum of the request for fossil fuels, renewable sources , and conservation R&D put together. With the enormous sums of money the government has poured into nuclear fission over the years, it seems that this energy source should be making it in the marketplace without further large infusions of research and development money.

"One element of the failure of this Administration is its failure to take into account the energy needs of the rest of the world. We in the industrial countries are the only people who can afford major investments in energy R&D. And yet historically we have made those investments as if the world's only energy needs were those that could be met by technologies appropriate to our own economic and cultural contexts."

Over past weeks, indications are that Keyworth is opening himself up to outside advice from some of the science policy old guard. These are ideologically neutral individuals who won't speak for publication but feel strongly that the White House science function is more crucial than ever in meeting a whole convergence of domestic and international problems.

What they bemoan most is the decline of independent science advice in the national security and arms control areas. To their observation, Keyworth and his Science Council have less than minimal input into the National Security Council and the Pentagon. "A science office is good for balancing the Pentagon," says one. "And it should co-relate to the National Security Council. This Administration has not followed that, and, of course, President Carter destroyed the whole idea. Keyworth's council was supposed to function like PSAC, but it doesn't. It is not doing any national security work, and in the process, Keyworth has been out of step with the national science community over Star Wars."

The charge is a serious one. And it is easy to see how Keyworth could be in a bind as he melds with the scientific establishment he hardly knew in his first few months. He reports that he lately has been reading the book, "Science Advice to the President," edited in 1980 by William T. Golden, a New York investment banker who in the 1940s first suggested the idea that the President should have a science adviser.

"My impression," says Golden, "is that Keyworth is getting better and better all the time, especially when you consider that he started with the shortcoming of having no experience in Washington. People tell me that his Science Council is not encouraged to generate many new ideas. They're more a sounding board for him. As a result a narrow 'gene pool' of ideas is available to the President."

Adds Golden: "I think PSAC would introduce new ideas to the President himself, in coordination with the science adviser. Members would have a feeling of being useful in a way that being an adviser without Presidential appointment would not have. They would get encouragement to think of novel ideas and they would want him to hear them. But I really have no reason to think Reagan wants the introduction of outside ideas. Perhaps in his second term, Reagan will be more interested to hear them, however."

What is obvious is that science advice is much more complicated than it was in its early days of sputnik and antiballistic missile development. Then, its politics was minimal, and Presidents Eisenhower and Kennedy genuinely knew they needed a counterbalance in advice to weigh against schemes of a technologically ambitious but unsophisticated military.

Today, science and technology riddle politics and policy. Their logic, in fact, tests it. So the political advisers around any President may want to protect him or her from too much logical advice. In other words, science policy may have become so mature that it must be kept at bay in an era of subtle and not so subtle media-delivered propaganda. Few should be surprised, then, if Reagan's staff decides that eliminating OSTP serves the interests of his second term. □

Industrial Gases Settling into Slower Growth Pattern

Slowing rate of consumption of oxygen, nitrogen, and supply-plagued carbon dioxide plus capacity shakeout points to maturing industry

Bruce F. Greek, C&EN Houston

The industrial gases industry shows many signs of maturing. It has recovered very well from the recession. Its growth, excluding swings from recessions, is settling down to 1.5 to 2.0 times that of the gross national product—except for carbon dioxide because of its difficult supply situation. And the industry's excess capacity has been reduced through the shutdown of obsolete plants and little new construction in the past two years.

Production at air separation plants in 1984 will be up 10 to 15%. This increase includes both nitrogen and oxygen. New highs in output of nitrogen will be set this year and likely will continue to be set in future years. Production of oxygen, however, though up significantly, could be a long time in matching its previous high set in 1979.

As might be expected in the maturing of products, contrasts also are developing. Differences between nitrogen and oxygen in their outlooks are examples. Fast-growing uses have been developed for nitrogen, helping to spur plant building and technology development. But oxygen has had prospects of high growth demands dashed by big cutbacks in projects to gasify coal.

Key Chemicals

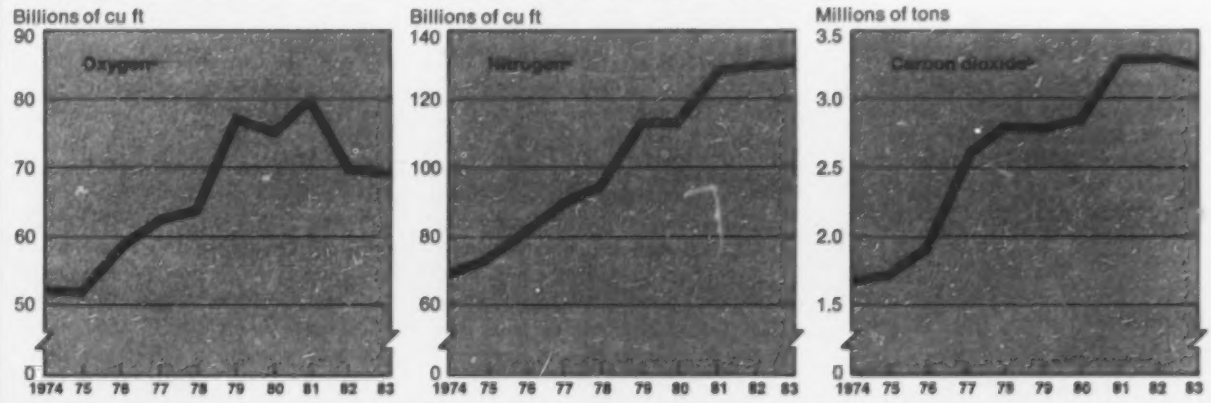
The enhanced oil recovery (EOR) uses of nitrogen likely will keep demand for this gas moving ahead for many years with only the possibility of a large decline in world oil prices as a potential damper on growth. Use in this area likely will pull along total nitrogen consumption even as demand in the metals industry declines and rises with the economy.

In contrast, oxygen faces much slower growth if the restructuring of the steel and chemical industries continues. If imports of steel and chemicals replace domestic production, then oxygen demand could falter in the U.S. Even the use of oxygen in partial oxidation processes could slow as a result of the slowing in demand for heating oils and a leveling of demand for gasoline.

Carbon dioxide also is confronted with little growth in production. But this is not because of a lack of demand. Supply problems have plagued carbon dioxide producers for quite some time, and they seem to be getting worse. Because carbon dioxide is a coproduct, it depends on production of the wanted product. In the case of ammonia production, the largest source of carbon dioxide, a shift has been under way to foreign sources, which have access to much lower-cost natural gas.

For a more detailed look at these industrial gases, see the following pages.

Merchant shipments of industrial gases show divergent patterns



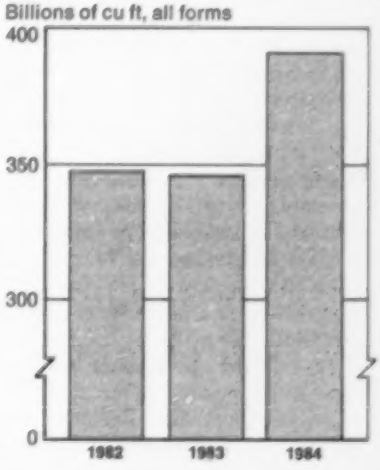
a Cylinder and bulk delivery. b Data for 1974 through 1980 believed understated; reporting for 1981 through 1983 not comparable with earlier data.
Source: Bureau of the Census

Oxygen

O_2

- *Demand higher*
- *Capacity holding*
- *Prices up slightly*

PRODUCTION



TOP FIVE PRODUCERS

Air Products, Airco (BOC Group), Big Three Industries, Union Carbide, Liquid Air

HOW MADE

Separated from air at low temperatures; pressure-swing adsorption using various molecular sieves

MAJOR END USES

Primary metals manufacture 30%, metals fabrication 30%, chemical manufacture 20%, partial oxidation processes 10%

FOREIGN TRADE

Negligible

PRICES

Merchant sale list prices 53 cents per 100 cu ft plus delivery and equipment charges

Oxygen production during 1984 will keep pace with the general economic recovery, probably increasing about 12 to 14%. This gain will follow a flat year in 1983, after a decline of nearly 20% in 1982. Production of oxygen in 1984 likely will reach 390 billion cu ft, still well below the 430 billion cu ft produced in 1981.

Thus, though oxygen production has improved, it is yet to return to its former highs. These highs could be a long time coming. The major uses of oxygen, which are in the metals industries and which take some 60% or so of consumption, could lag for many years, holding down total demand. Hopes for topping former output levels, therefore, depend on development of other current uses and new uses.

Capacity to produce oxygen either by air separation or by pressure-swing adsorption continues to be in substantial oversupply, especially for captive and for pipeline delivery sales. Most of this oxygen production goes to steelmaking and chemical manufacture. New capacity being built is small because of this oversupply, with most new capacity going to replace obsolete units or to meet demand in a new location. Until some of the new uses expected for oxygen get moving, capacity expansions will be minor.

Steelmaking accounts for nearly one third of oxygen production. Consumption of oxygen for all of 1984 depends heavily on how well steel does during this quarter of the year. Earlier in 1984, demand for steel rose strongly. Prospects then were good for the entire year. A long auto strike seemed to be unlikely during the second quarter, causing steel production to exceed demand even with most auto plants running nearly all out. Inventories of sheet steel used in autos and in appliances rose to levels considered excessive, partly aided by imports of steel. During the third quarter, spurred by the short strike of auto workers at General Motors, inventory cutting began and continues even now.

At the same time, some steelmakers expected capital goods demand for steel—large beams and plate, for example—to increase during the second half of the year. Inventories of these forms of steel also rose. Now that it has become clear that this area of steel demand will not be very large in 1984, inventory cutting is under way where possible.

The other major area of metals' use of oxygen is in fabrication, both cutting and welding of steel. This use has declined during recent years and seems unlikely to grow very much until another strong capital goods boom occurs.

Chemicals manufacture accounts for nearly 20% of oxygen consumption. Ethylene oxide production accounts for about half of this consumption. Other chemicals using oxygen in their production include acrylic acid, propylene oxide, and vinyl acetate.

Partial oxidation processes could be included with chemical manufacture but are more specialized, with two processes accounting for most of the consumption. One is the partial oxidation of the residual fraction of petroleum to make synthesis gas or hydrogen alone. The other process involves use of oxygen in fire flooding of oil reservoirs to enhance oil recovery. This use works best with heavy crudes and offers an alternative to use of carbon dioxide in enhanced oil recovery, but it remains dependent on special oil production situations.

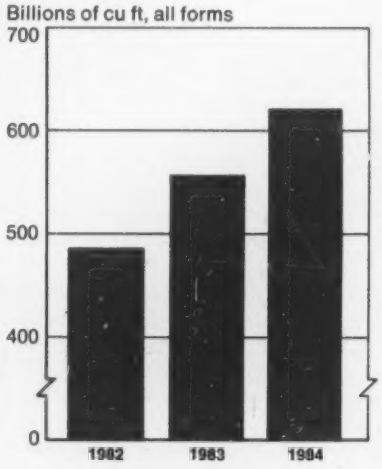
These new uses indicate that a degree of change is under way in oxygen consumption, which might help producers over the long term. Steel and its fabrication could be declining slowly as a use because of imports of both steel and products of steel such as autos. Chemicals' use of oxygen also may later be hurt by imports. New uses, such as partial oxidation processes or air enrichment, soon may grow fast enough to offset any declines in older uses and keep demand for oxygen rising.

N_2

Nitrogen

- ***Demand stronger***
- ***Capacity holding***
- ***Prices improved***

PRODUCTION



TOP FIVE PRODUCERS

Air Products, Airco (BOC Group), Big Three Industries, Union Carbide, Liquid Air

HOW MADE

Separated from air at low temperatures; pressure-swing adsorption using various molecular sieves

MAJOR END USES

Blanketing atmospheres for chemical processing 25%, enhanced oil recovery 20%, electronics manufacturing 15%

FOREIGN TRADE

Negligible

PRICES

Merchant sale list prices 49 cents per 100 cu ft plus delivery and equipment charges

Production of nitrogen is still moving ahead smartly. In 1984, output for various uses, except for making ammonia, could exceed 620 billion cu ft, up about 12% over 1983 production. This follows a gain of about 15% in 1983. Such steady increases in production contrast with production gains for oxygen, which, although good in 1984, were on hold in 1983.

All of nitrogen's large end uses are continuing to grow, although some have significantly better growth rates than others. Some, such as enhanced oil recovery (EOR), will grow at twice the average rate of 12% during 1984. Others, such as metals uses, will be half the average growth rate. The gain in EOR consumption of nitrogen, a relatively specialized area, has been so large that its share of total nitrogen consumption has increased and has taken a percentage point or so out of each of the other major uses.

EOR will account for about 20% of total nitrogen production or about 120 billion cu ft of nitrogen in 1984. Most of this consumption will come from air separation plants dedicated to making nitrogen for EOR. Such plants are designed to maximize nitrogen production with the oxygen returning to the off-gases stream. Usually, these air separation plants are so far from an oxygen use site that it is uneconomical to ship the oxygen. Such plants contrast with those installed at or near steel mills that have oxygen as their primary product for use in basic oxygen furnaces.

Several different uses of nitrogen are involved in EOR projects, helping to spur demand. The particular application at a given location depends heavily on the geology of the reservoir and on economics of potential oil production. The largest use by far is pressure maintenance to drive crude oil through the reservoir to producing wells. Sometimes nitrogen is used as the driving force to move the alternate slugs of water and of carbon dioxide that are put into a reservoir. Nitrogen use in EOR will be up 20 to 25% over last year, partly because new air separation plants have been coming on stream to supply this nitrogen.

Chemical processing is feeling the challenge from EOR as the largest use of nitrogen. Most chemical processing uses are as blanketing atmospheres, particularly in vessels where polymerizations and other specific reactions are run. Other uses in chemical processing run the gamut from fire prevention to drying and purging. Conveying polymer pellets has become an increasingly important use, although as yet it is relatively small volume. The various chemical plant uses could amount to 150 billion cu ft this year, or about 25% of total consumption.

Electronics manufacturing has been another major market for nitrogen. Growth in this area has slowed appreciably, however, from more than 20% annually to about 10%. Still, the rise has continued to give high profit margins to suppliers of nitrogen, because of the increasingly stringent purity requirements of many electronics manufacturers. Manufacturers have been willing to pay premium prices for nitrogen with impurities in the parts-per-million range. The volume of use of this kind of nitrogen, of course, is small when compared to the volume used in most applications.

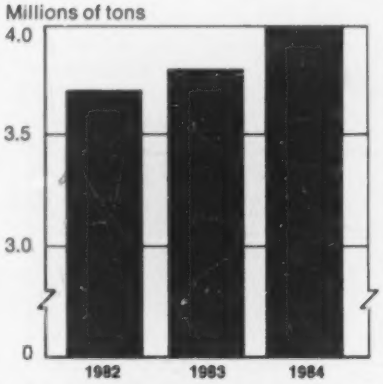
Among other uses, those in the metals processing industries, largely steel, may account for about 15% of total consumption. Because of their heavy dependence on the general economy, these uses as a group swing up and down significantly. Their growth probably will average about 5% annually over the long term. Food freezing, especially the more valuable items such as meats, poultry, and seafood, has slowed as a consumer of nitrogen, largely because the demand for fast food has slowed. Aerospace, cryogenic grinding, glass making, medical, and others as a group all will grow slowly as nitrogen uses. However, they probably won't help overall growth much.

CO_2

Carbon dioxide

- ***Supply limited***
- ***Capacity inadequate***
- ***Prices varying widely***

PRODUCTION[a,b]



a Recovered for merchant sale and captive uses excluding urea manufacture; does not include carbon dioxide recovered for use in enhanced oil recovery.
b C&EN estimates.

TOP FIVE PRODUCERS

Airco Industrial Gases, Air Products, Chemetron, Liquid Carbonic, UGI

HOW MADE

Recovered from gas streams produced for ammonia manufacture, hydrogen processing, fermentation processes (ethanol), chemicals manufacture, and natural sources

MAJOR USES (nonoilfield)

Refrigeration 30%, beverage manufacture 25%, chemical manufacture 10%, welding 10%

FOREIGN TRADE

Exports—negligible, imports—small, 1 to 2% of consumption

PRICES

List prices vary widely, but average about $75 per ton

Carbon dioxide could be unique among major volume industrial chemicals. It has the unusual advantage that more of this gas could be sold to its merchant markets if it were available. This supply limitation, however, applies to just a small part of the demand for carbon dioxide—the merchant market amounts to about 5% of total consumption. The remainder of carbon dioxide production and consumption involves captive or near-captive use in petroleum and natural gas operations.

The unusual supply situation for merchant carbon dioxide stems from the fact that it is a frequently unwanted coproduct in the manufacture of some other material. Most of the carbon dioxide going to merchant and commercial markets is captured from the production of ammonia and hydrogen by reforming natural gas, from making ethanol and other products by fermentation, and from making other chemicals. Most of the carbon dioxide used in enhanced oil recovery (EOR) comes from producing natural gas containing high concentrations of carbon dioxide.

These two areas of carbon dioxide production and consumption are so separate that they seldom are considered together. Production data for the smaller merchant supply of carbon dioxide are reported to the Bureau of the Census, and estimates of use patterns are made by various producers.

No data, however, are reported on the captive production from gas wells and consumption in EOR. Here carbon dioxide frequently is produced from gas wells owned by an oil and gas company and is consumed entirely in the company's EOR operations. In other cases, the carbon dioxide is sold under long-term contract by the producer to a single, nearby consumer. The carbon dioxide involved in EOR operations generally is not considered to be an industrial gas because data are not available, it comes from a single source, and it has a single use.

In the merchant category, production date seem to be underreported, according to some industry sources. This is due partly to the fragmented sources and partly to the kind of operations—some are seasonal—that yield coproduct carbon dioxide.

Production of carbon dioxide from ammonia plants, its largest source, is estimated to increase 5% this year to about 4 million tons, raising the availability of carbon dioxide. Production of hydrogen, another carbon dioxide source, for use in refinery hydrogenation processes also rose some this year, increasing the availability of carbon dioxide, but to a much smaller degree. However, a substantial part of this carbon dioxide supply may move to captive uses in EOR operations of the refinery's parent company.

Recently, a new source of carbon dioxide—grain fermentation to make ethanol for fuel uses—began to develop rapidly. But again, unfortunately for carbon dioxide supply, the growth of ethanol use for automotive fuel depends also on economics and politics such as tax incentives for plant construction, world demand and prices for grain, and crude oil and refined product prices.

With supply as the major problem for carbon dioxide producers, the incentive to develop uses remains limited. The major uses of carbon dioxide, such as refrigeration and making beverages, are projected to grow at about the same rate as that of the gross national product.

One new use with good potential for growth has resulted from the approval earlier this year by the Environmental Protection Agency of carbon dioxide as a fumigant for stored grain. Safety and the lack of any residue could make this use soar.

The merchant carbon dioxide business, tiny when compared to EOR, may not be growing very much because of limited supplies. But with a few uses for which no substitutes exist, the business may be a good one for those producers willing to struggle to meet the demand.